

FILE COPY

FOREST INSECT LABORATORY,
UNIVERSITY OF CALIFORNIA,
BERKELEY, CALIFORNIA.

428.e

UNITED STATES DEPARTMENT OF AGRICULTURE

BUREAU OF ENTOMOLOGY

FOREST INSECT INVESTIGATIONS

FINAL REPORT
ON ROLE OF ANTS, CENTIPEDES AND RODENTS
DESTRUCTIVE TO BROODS OF THE MOUNTAIN PINE BEETLE
EXPOSED BY THE PEELING METHOD OF CONTROL

By
H. J. Rust
Senior Scientific Aid

Forest Insect Field Station
Coeur d'Alene, Idaho
April 29, 1931

ROLE OF ANTS, CENTIPEDES AND RODENTS
DESTRUCTIVE TO BROODS OF THE MOUNTAIN PINE BEETLE
EXPOSED BY THE PEELING METHOD OF CONTROL

Table of Contents

	Page
INTRODUCTION - - - - -	1
SCOPE - - - - -	2
LOCATION AND TIME OF EXPERIMENTS - - - - -	3
TOPOGRAPHY AND GROUND COVER OF THE AREAS - - - - -	3
Lodgepole pine, Bitterroot National Forest - - - - -	3
White pine, Coeur d'Alene National Forest - - - - -	4
White pine, Clearwater National Forest - - - - -	4
White pine, Kaniksu National Forest - - - - -	4
CLIMATOLOGICAL SUMMARY OF THE AREAS - - - - -	6
Part I:	
METHODS AND MATERIALS - - - - -	7
RESULTS OF CAGED EXPERIMENTS, LODGEPOLE PINE AREA,	
Cage - Type I - - - - -	8
WEATHER CONDITIONS - - - - -	-10
WHITE PINE AREA, COEUR D'ALENE NATIONAL FOREST, IDAHO,	
Cage - Type I - - - - -	10
WHITE PINE AREA, COEUR D'ALENE NATIONAL FOREST, IDAHO,	
Cage - Type II - - - - -	13
LODGEPOLE PINE, BITTERROOT NATIONAL FOREST, MONTANA,	
Cage - Type III - - - - -	14
Part II:	
LODGEPOLE PINE AREA, BITTERROOT NATIONAL FOREST, MONTANA,- -	15
SURVIVAL PLOTS, LODGEPOLE PINE AREA - - - - -	17
RESULTS OF OBSERVATIONS - - - - -	18
WHITE PINE AREA, COEUR D'ALENE NATIONAL FOREST, IDAHO - - - - -	20
WHITE PINE AREA, CLEARWATER NATIONAL FOREST, IDAHO - - - - -	24
WHITE PINE AREA, KANIKSU NATIONAL FOREST, WASHINGTON - - - - -	26
PREDATORS DESTROYING THE EXPOSED PROGENY OF THE MOUNTAIN PINE BEETLE - - - - -	29

Table of Contents

	Page
ANTS INHABITING THE AREAS - - - - -	30
BITTERROOT NATIONAL FOREST, MONTANA - - - - -	30
COEUR D'ALENE NATIONAL FOREST, -IDAHO- - - - -	30
KANIKSU NATIONAL FOREST, WASHINGTON - - - - -	30
ANT ACTIVITIES - - - - -	31
CENTIPEDES - - - - -	33
GROUND BEETLES - - - - -	34
RODENTS - - - - -	34
ABUNDANCE OF SMALL RODENTS - - - - -	35
SMALL RODENTS TRAPPED ON THE AREAS AND LISTED IN ORDER OF THEIR IMPORTANCE - - - - -	36
SUMMARY AND CONCLUSIONS - - - - -	39
ACKNOWLEDGMENTS- - - - -	40

ROLE OF ANTS, CENTIPEDES AND RODENTS
DESTRUCTIVE TO BROODS OF THE MOUNTAIN PINE BEETLE
EXPOSED BY THE PEELING METHOD OF CONTROL

INTRODUCTION

The peeling method of control was devised by the Forest Insect Division of the U. S. Bureau of Entomology, to meet the demands of timber owners for protection against tree killing barkbeetles that develop between the bark and wood. This treatment was based on the assumption that by removing the bark from infested trees during the feeding or larval stage the brood would be deprived of their natural food supply and with exposure to the weather, their destruction would soon follow. The first application of this method of control was at Palmer Lake, Colorado in 1905 (1). During the following three years, this same treatment was applied on a large scale against the Black Hills beetle (D. ponderosae Hopk.) in South Dakota when, according to official reports and correspondence, approximately 15,000 infested trees were peeled.

This method of control continued in use up to 1926 in the lodgepole pine stands, and to the present time in the white pine stands in the Rocky mountain region. During the extensive control operations against the mountain pine beetle outbreak on the Beaverhead National Forest, Montana in 1926-27-28, it was found that the infested trees could be cut, decked and burned much more cheaply than they could be peeled. From then on the cutting and burning, or the burning-standing method has been used in preference to

(1) Hopkins, A. D. Barkbeetles of the Genus *Dendroctonus* U.S.D.A. Bur. Ent. Bul. 83, pt. 1. 1909. Washington, D. C.

the peeling method in the lodgepole pine region. In the white pine stands, both the peeling and burning methods are used. In carrying out the peeling method of control, the operation has generally been conducted from early spring, or as soon as the weather conditions in the forests would permit, until the latter part of June. By this time the beetle broods have usually reached the callow adult stage and the artificial release is no longer considered practical. It is during the latter period of control work, or after the broods of the barkbeetle have reached the post-feeding stage (as prepupal larvae, pupae, and callow adults) that the possibility of the exposed progeny reaching maturity in the duff becomes apparent. The assumption that exposure and starvation would destroy all the progeny of the barkbeetle exposed by the peeling method remained unquestioned until a few years ago, when it was found that if protected from predators, the post-feeding stages could reach maturity in the duff.

The purpose of this study was to determine whether enough of the progeny of the mountain pine beetle exposed by the peeling method of control could reach maturity and attack healthy trees in such numbers as to lessen the value of this method.

SCOPE

The experimental work in connection with this study in both the lodgepole and white pine stands was divided into two parts; Part I, to determine the possibility of the broods of Dendroctonus monticolae attaining maturity when uncovered by the peeling method of control and allowed to remain on the ground but protected from all predators; and Part II, to determine the mortality of these broods when uncovered by the peeling method of control and allowed to remain on the forest floor unprotected.

LOCATION AND TIME OF EXPERIMENTS

The areas selected for this study were in regions where an outbreak of the mountain pine beetle existed. The study was first instituted in a lodgepole pine stand on the Bitterroot National Forest near Sula, Montana. This area was chosen as being representative of this type of timber in the northern Rocky mountain region. Areas selected for the extension of the study into the western white pine stands of Idaho and Washington were located on the Coeur d'Alene, Clearwater and Kaniksu National Forests. On the first two of these areas artificial control measures were being conducted while the survival study was in progress.

The initial study in lodgepole pine was begun on the Bitterroot during the spring of 1928 and concluded there during the summer of 1929. It was begun in the western white pine stands on the Coeur d'Alene area during the spring of 1929. It was continued on the Clearwater area during the spring of 1930 and the conclusion of the study in western white pine was made on the Kaniksu area during the summer of 1930.

TOPOGRAPHY AND GROUND COVER OF THE AREAS

Lodgepole Pine, Bitterroot National Forest

The area selected in the lodgepole pine stands is a portion of the drainage basin of the East Fork of the Bitterroot River where it is joined by the tributaries Bertie Lord and Meadow Creeks, twelve miles east of Sula, Montana. Large flats are prevalent along the bottom of the canyon through which the main stream flows and an occasional small flat along the course of the tributaries. The sides of the canyons rise rapidly from the outer edge of the flats or from the border of the streams from an elevation of 4900 to 5400 feet. On the south side of the River these ridges form part of the

foothills of the Continental Divide which has an elevation of 7000 feet in the vicinity of the area of study. Very little reproduction, brush, or windfalls were present on the area, particularly on the south, east, and west exposures.

WESTERN WHITE PINE COEUR D'ALENE NATIONAL FOREST

The area selected for western white pine is a part of the Steamboat Creek drainage, known as the East Fork. The main branch and tributaries of this stream are confined in deep canyons. Very little level ground is found along the streams above the forks. The slopes rise rapidly from the creek level of 3100' to form ridges of 4100 feet elevation. These ridges form part of the lateral system of the main divide between the Steamboat Creek and the other large drainages of the forest. The main divide reaches an elevation of 5100 feet.

The steep slopes confining the streams, support a heavy stand of white pine intermingled with hemlock, white fir, larch, and cedar on the lower elevations, and with Douglas fir and lodgepole pine on the higher ridges. An estimate by the U. S. Forest Service of the volume of white pine on the four sections used in the study is given at 37,000,000 B.F. One section alone carrying 14,660,000 B.F. In addition to the heavy stand of timber a fairly dense understory of reproduction, shrubs, and flowering plants are also present, particularly along the borders of streams and on the crests of ridges. Windfalls were common throughout the area. The dense crown canopy of trees has a decided influence on the retention of moisture by the duff during the spring season.

WESTERN WHITE PINE
CLEARWATER NATIONAL FOREST, IDAHO

The 1930 control area in this region was scattered over nine sections, but confined mainly between the Lolo and Musselshell Creeks. This area began at the Musselshell Ranger Station and extended south a short distance below the junction of the two confining streams which parallel each other for several miles. The many low ridges which confine the numerous small feeders heading in the dividing ridge between the two creeks produce a very broken and irregular stretch of country. A few small flats and meadows are present in the locality. Two sections representative of the control area were used in the survival experiment. A fairly heavy stand of white pine and cedar is found in the region and portions of the ridges are brushy and the streams bordered with a thick growth of willows and alder. A heavy blowdown occurred in the area in 1927 creating an unusual number of windfalls.

WESTERN WHITE PINE
KANIKSU NATIONAL FOREST, WASHINGTON

The area selected in the white pine stands on the Kaniksu National Forest was on the Sullivan Creek drainage at an elevation of 2800 feet. Large openings between the confining hills are fairly common, forming extensive flats along the lower half of the stream. One of these heavily timbered flats was selected as a suitable site for the survival study. On a portion of the area the crown canopy of trees was so dense that no small vegetation was present.

Table I summarizes the climatological data of the four regions.

TABLE I
ELEVATIONS, MEAN TEMPERATURES, AND PRECIPITATION
OF THE FOUR REGIONS IN WHICH THE STUDY WAS MADE (1)

Area of Survival Experiments	Eleva- tion	Timber Type	1929				1930			
			Mean Temp.		: Total Precipitation:		Mean Temp.		: Total Precipitation	
			May	June	May	June	May	June	May	June
Steamboat Creek										
Coeur d'Alene N. F.		White pine								
Idaho	3150	Hemlock	54.6	59.8	.67	2.82	53.2	59.5	4.27	1.53
Lolo-Musselshell Cr.										
Clearwater N. F.		White pine								
Idaho	3100	Cedar	55.4	62.0	1.53	3.44	56.1	62.2	3.10	2.57
Sullivan Creek										
Keniksu N. F.		White pine								
Washington	2800	Douglas Fir	51.8	57.5	.74	2.76	50.8	56.0	2.18	1.63
East Fork Bitterroot		Lodgepole								
River, Bitterroot N.F.		pine								
Montana	4900	Douglas Fir	50.8	57.4	1.13	1.08	51.2	58.0	0.36	.40

(1) The records were taken from the nearest U.S. Weather Stations as follows: Coeur d'Alene, Kellogg, Idaho; Clearwater, Pete King Ranger Station, Idaho; Keniksu, Priest River Experiment Station, Idaho; Bitterroot, Darby, Montana.

A comparison of the elevations in Table I shows the three white pine areas to be quite similar-- the lodgepole pine area much higher. The mean temperatures for the four areas over the two-year period varied but little. The greatest variation is found in the precipitation, particularly in comparing the two years. The rainfall on all the areas was much less in 1930 especially in the Bitterroot region.

Part I. METHODS AND MATERIALS

The possibility of the exposed broods of Dendroctonus monticolae reaching maturity in the duff if protected from all predators as outlined under Scope was determined by caged experiments.

Three types of cages were used. The first consisted of a light framework of wood covered with wire screen thought to be of a fine enough mesh to keep out predators but to allow sufficient ventilation. This cage measured six feet long, two feet wide, and one foot deep, and was divided into three separate compartments; one each for the larvae, pupae, and callear adults. On a site selected in an infested lodgepole pine stand, the ground cover and three inches of soil were removed from a space large enough to accommodate the cage. The soil and duff were replaced on the bottom of the cage so as to represent as nearly an undisturbed condition as possible. This type of cage was used in the initial study on the Bitterroot National Forest during May and June, 1928. A modified form of this type consisting of three separately constructed compartments each measuring two feet square, eighteen inches deep, and covered with a closely woven wire screen, was used on the Coeur d'Alene National Forest in 1929.

The second type of cage was formed by enclosing four feet of the basal portion of healthy white pine. Fine mesh wire screen was used for these cages. The screen was tacked securely around the bole of the tree, four feet from the surface of the ground, and formed into a funnel shaped cage; its bottom edge rested in a covered trench approximately one foot distant from the bole of the tree at the ground surface. No screen floors were used in these cages. Two of these cages were used on the Coeur d'Alene National Forest during the spring of 1929.

The third type of cage was an improved form of the second type. The improvement consisted of a closely woven wire screen floor fastened securely around the base of the tree, three inches below the ground level and fastened to the edges of the screen forming the cage. This type was used on healthy lodgepole pines on the Bitterroot National Forest during the summer of 1929, and was found to be the most successful.

Part I. RESULTS OF CAGED EXPERIMENTS, LODGEPOLE PINE AREA

Cage - Type I

The first type of cage as used in the infested lodgepole pine stand on the Bitterroot National Forest, was placed in position on June 6 and on the following day 120 larvae of Dendroctonus monticolae in several stages of development, 175 pupae, 130 callow adults were placed on the duff in their respective compartments. A few strips of bark from a near by infested lodgepole pine were dropped over the brood in each compartment to resemble a condition similar to that created by the bark dropped during the peeling method of control. It was believed that the best results from this experiment would be secured by leaving the duff and the Dendroctonus monticolae progeny undisturbed as much as possible until the final examination, therefore, only very brief inspections were made during the intervening time.

The first examination was made June 16, ten days after the brood was placed in the cage. Six square inches of duff were disturbed in the larval compartment, disclosing three active pupae. In the pupal compartment several of the bark strips were moved disclosing 11 active pupae, four of which were nearly ready to transform. In the adult compartment the beetles were found gathered in groups on the underside of the bark strips. A small section of freshly cut lodgepole pine was placed in the compartment at this time to determine whether the callow adults released before normal emergence would

successfully attack it. On the 22d. day of June a second examination was made. In the larval compartment the three pupae seen on previous occasion were still active. Three callow adults were seen clinging to underside of bark strip in the pupal section, and in the adult compartment, three attacks were noted on the section of lodgepole. Boring dust was visible and it was apparent that egg galleries were under construction. On June 24, or 18 days after the brood was placed in the cage, it was found that a number of small ants had gained entrance into the larval and pupal sections, and were crawling about in the duff. At this time a small section of freshly cut lodgepole pine was placed in the pupal compartment. On August 11, the final examination was made of the larval compartment. All the duff and soil were removed and carefully examined. No evidence of Dendroctonus monticolae brood was found. Six small centipedes were collected from the duff, and it is believed these chilopods and some small ants that had entered the cage had disposed of the mature larvae and transformed pupae. The smaller larvae which were still in the feeding stage, no doubt died from starvation and exposure. On August 22, the final examination was made of the pupal and adult compartments. Four attacks with short egg galleries were found in the small section of lodgepole in the pupal compartment. No evidence of the balance of the pupae could be found. They, no doubt, were destroyed by ants and centipedes. On the section of wood taken from the adult compartment, 27 egg galleries were disclosed when all the bark was removed. The longest gallery measured six inches in length, and contained larval mines with small larvae in the lower portion and eggs in the upper end. No ants or centipedes were seen in this compartment and it is not known what became of the adults that failed to attack the section of lodgepole placed in the cage.

WEATHER CONDITIONS

Table II shows the weather variations and rainfall between the dates of June 7 and August 22, 1928. The weather observations were made at a temporary field station a quarter mile distant from the location of the experiment.

TABLE II
THE TEMPERATURES AND RAINFALL NEAR SULA, MONTANA
BETWEEN JUNE 7. AND AUGUST 31, 1928

	: Average	: Range of	: Rainfall
	: Maximum Minimum	: Maximum Minimum	: in inches
June 7-30	: 67° F. 36°	: 52°- 84° 22°- 49°	: 0.83
July 1-16 (no data 17-31):	77° 39°	: 63°- 93° 32°- 48°	: 0.79
August 1-31	: 78° 33°	: 60°- 96° 23°- 48°	: 0.85

Considerable rain fell during the experiment. This amount of moisture with a lack of sufficient ventilation produced a very mouldy condition in the duff on the floor of the cage. Temperatures below freezing were recorded frequently between June 7 and August 22, and the higher air temperatures lasted only a few hours during the day. The combination of low temperature and mouldy condition of the duff was apparently very unfavorable for the development of the exposed progeny of the mountain pine beetle.

Part I. WHITE PINE AREA, COEUR D'ALENE NATIONAL FOREST, IDAHO

Cage - Type I

The modified form of the first type of cage was used in an infested white pine stand on the Coeur d'Alene National Forest. The site selected for the location of these cages was among a group of white pines growing on a steep east facing slope. A number of the trees in the group were infested by the mountain pine beetle. A portion of the hillside was dug away forming a level place large enough to accommodate the cages. Enough duff to cover the floor of the cages was taken from the selected site and

roasted over a fire sufficiently to kill any predatory insect life that might be present.

The cages were placed on May 16, and on the following day 750 mountain pine beetle larvae collected from a near by infested tree, were placed on the duff in the larval cage and covered with a few pieces of white pine bark taken from a tree killed by the mountain pine beetle two years previously. A glass-rod-type of thermometer was placed in the duff on the floor of the cage for recording temperatures. On June 3, a few square inches of duff were examined, and one active pupa was seen. Owing to incessant rains, lack of sunshine, and sufficient ventilation, the duff in the cage was becoming very wet and mouldy. On June 5, 250 additional larvae were added bringing the total up to 1000. On June 13, three active pupae were seen in a small section of the duff. After the cessation of a 48 hour rainstorm ending June 19, the entire duff in the cage was examined. Twelve dead and 2 active pupae were all that could be found of the exposed brood. The duff was removed and dried over a fire. The dried duff was replaced in the cage on June 21, and the experiment continued with 200 Dendroctonus monticolae larvae. At this time, the cage was raised a couple of inches from the ground and supported in this position by a small flat stone under each corner. It was found that this method gave additional ventilation and helped prevent the accumulation of mold.

On June 27, it was found that a number of small ants (Lasius niger var. americanus Emery) had gained entrance, possibly through a damaged mesh in the bottom of the cage, and were placing many of the Dendroctonus monticolae larvae in a pile under the duff in one corner of the cage. In disturbing a portion of the duff where the ants were working, 16 active pupae were disclosed. All the ants that were seen inside were destroyed. A

small section of freshly cut white pine, 2 feet long and six inches in diameter was placed in the cage to determine if any of the brood would survive and attack. Owing to absence, the final examination was not made until September 30.

No Dendroctonus monticolae pupae could be found in infested white pine until May 31, at which time 150 were placed on the duff in the pupal cage. On June 19, the duff in this cage was found to be in such a wet and mouldy condition that it was removed and dried. All the pupae had died, no doubt, from exposure. On June 21, the duff was replaced and 100 active pupae added, and the cage was raised from the ground similar to the one containing the larvae. A small section of freshly cut white pine was also placed in this cage. The final examination was not made until September 30.

Callow adults were not available until June 26, at which time 300 were placed on the duff in the adult cage, and covered with small strips of bark. A small section of white pine was placed in the cage to determine if adults released before normal emergence would successfully attack. On September 30, a final examination was made of the three cages. No attacks on inclosed section of white pine in larval and pupal cages were found, neither any trace of the exposed broods. The section of white pine from the adult cage contained 26 attacks with egg galleries constructed. Seven of these galleries were 12 inches in length, and the broods, while below normal in number, probably owing to the crowded condition, consisted of 85 per cent callow adults, 10 per cent pupae, and 5 per cent larvae.

TABLE III
TEMPERATURES OF DUFF IN DENDROCTONUS MONTICOLAE
LARVAL CAGE AT VARIOUS DATES AND TIME OF DAY IN 1929

<u>Date</u>	<u>Time of day</u>	<u>Temp. F.</u>
May 17	7:30 a.m.	41°
" 17	12:00.m.	49°
" 17	4:30 p.m.	49°
" 20	1:00 p.m.	52°
" 21	7:30 a.m.	46°
" 22	1:30 p.m.	57°
" 23	8:00 a.m.	50°
" 26	7:35 a.m.	40°
" 27	10:00 a.m.	47°
" 31	11:00 a.m.	52°
June 5	12:30 p.m.	57°
" 20	10:30 a.m.	46°
" 22	12:30 p.m.	56°
" 25	8:00 a.m.	58°
" 26	10:30 a.m.	61°

Owing to frequent cold rains, hailstorms, lack of sunshine, and insufficient ventilation, the temperature of duff in the cages during May and early June was so low as to greatly retard the development of the confined broods of D. monticolae. The broods released by the peeling method and covered with bark strips were subjected to the same low temperatures and amount of rainfall, but as the duff had a good circulation of air the extreme mouldy condition was not present and the mortality from exposure was much less than in the cage.

Part I. WHITE PINE AREA, CONUR D'ALENE NATIONAL FOREST, IDAHO

Cage - Type II

The cages under Type I proved so unsatisfactory, that it was decided to try out another caging method. Two green standing white pines, eight inches in diameter, breast high, were selected and wire screen cages were constructed around the lower four feet of the bole. Owing to the steepness

of the slope on the site selected for the experiment, the soil and duff on the lower side of the trees was raised to a level with the uphill side, making an even dirt floor for the cages. No screen was used for forming the bottom of the cages, nor any means taken to keep ants away from the enclosures. Two hundred and fifty Dendroctonus monticolae larvae were placed on the duff in one cage and 100 pupae in the other cage. Owing to absence, the final examination of the cages was not made until September 30, 1929, at which time the screen was removed from the two trees. No attacks were found on the trees. The duff was in good condition and it is believed that the D. monticolae progeny were destroyed by ants, probably (Lasius niger var. americanus) entering the cages through the dirt floor. This species was found nesting in the ground at the base of white pine trees, a number of which were passed up in the selection for the cages owing to the presence of these ants.

Part I. LODGEPOLE PINE, BITTERROOT NATIONAL FOREST, MONTANA.

Cage - Type III

In continuing the caged experiment in the lodgepole pine area in 1929, it became apparent that if the desired results were to be secured, extra precautions to exclude ants would be necessary. Two green standing lodgepole pines, eleven inches in diameter, breast high, were selected and wire cages were built around the base of each tree. In constructing these cages, a wire screen floor was fastened securely around the base of the trees, three inches below the top level of the soil. The sides of the cages were formed by a large piece of screen tacked at the top to the tree and fastened to the screen floor at the bottom. The cages were large enough to allow considerable air space. A layer of duff consisting of fallen lodgepole pine needles and small twigs was placed on the sifted

soil on the bottom of each cage. Two hundred and twenty-five D. monticolae larvae were placed on the duff in one cage and 100 pupae in the other. An effort was made to keep ants away from the cages by placing liquid tanglefoot around the joint at the top of the cages and where sides were joined to the bottom. A shallow trench was made around each cage. In one trench old crank case oil was used and in the other, heavy axle grease. Shortly after completing the latter cage, a bear foraging for ants and grubs in the old stumps near by was apparently attracted to it by the axle grease. The cage was found totally wrecked and a large portion of the grease missing. The pupal cage, only a few feet distant was not disturbed. A new cage was constructed around the base of another green standing lodgepole, and 50 larvae were exposed on the duff. Heavy cup grease and tanglefoot was used at the base of this cage.

In spite of all the precautions taken, ants finally gained entrance into the pupal cage, and destroyed nearly all of the first placing. One hundred pupae were added to replace them, and more oil was poured in the small trench around the base of the cage. The final examination of both cages was made on September 25, 1929, at which time the following results were recorded:

Larval cage

Eighteen successful attacks were found on the portion of the tree confined in the cage. The tree was heavily attacked by Dendroctonus mon-
ticolae in the portion above the wire screen cage.

A comparison of the attacks in the cage with those above outside the cage is as follows:

<u>Inside the cage</u>	<u>Outside the cage</u>
Total number of attacks - 18	Total No. of attacks for comparison - 18
" " of gallery inches - 184	" " " gallery inches - 181
Average gallery length - 10.2"	Average gallery length - 10.0"
Shortest " containing brood - 4.5"	Shortest " containing brood - 5.5"
Longest " " " - 22.0"	Longest " " " - 23.0"

Pupal cage

The tree around which the pupal cage was constructed had 42 attacks and was also attacked by Dendroctonus monticolae in the portion above the cage. This attack occurred a week or ten days later than the attacks inside the cage.

A comparison of the attacks in the cage with those above outside the cage is as follows:

<u>Inside the cage</u>		<u>Outside the cage</u>	
Total number of attacks - 42		Attacks for comparison - 20	
" " " gallery inches - 383½		Total No. of gallery inches - 142	
Ave. length for the 1st. 20 gall. 9.0"		Ave. length for the 20 gall. - 7.1"	
" " " " 42 galleries - 9.1"			
Shortest gall. containing brood - 2.0"		Shortest gall. containing brood - 2.5"	
Longest " " " - 27.5"		Longest gall. " " - 14.0"	

The average length of galleries for the outside as compared with those inside was no doubt influenced by the age of the attacks; those inside the cage being a week or ten days earlier.

PART II

The possibility of exposed broods of Dendroctonus monticolae reaching maturity in the duff when exposed to the weather and predators as outlined under Scope, Part II, was determined by a number of plots established beside or near peeled infested logs and supplemented by observations at groups of treated logs on areas where the peeling method of control was being applied.

Part II. LODGEPOLE PINE AREA, BITTERROOT NATIONAL FOREST, MONTANA

Thirty-four plots for observing the survival of exposed progeny of the mountain pine beetle were used in the lodgepole pine area. A brief tabulated description of these plots is shown in Table IV.

TABLE IV
TABULATED DESCRIPTION OF 34 SURVIVAL PLOTS WITH THE EXPOSED BROOD OF
DENDROCTONUS MONTICOLAE IN THE LODGEPOLE PINE AREA, BITTERROOT NATIONAL FOREST

Plot:	Size	Ele-	Ex-	Location of	Depth:	No. of <u>D.</u> <u>monticolae</u>	Duration:	Biological
Sym-:Date: of	va-:po-:	tion:sure:	plots	of	of	placed on plot	of	factors dis-
bel :1928:Plot				duff	Ground cover	Lar. Pup. Adults: Total:	plot	D.m. progeny
1	:6/15:1 sq.ft:	4900:	S	:on flat near logs	:1 $\frac{1}{2}$ "	:Forest litter	: 34 35 25 : 95:	6 $\frac{1}{2}$ hrs.:Ants
2	:6/19:" " "	:5000:	N	:on slope " "	:8 $\frac{1}{2}$ "	:Moss and plants	: 50 50 50 : 150:	12 days:Centipedes
3	:6/21:" " "	:4900:	S	:on flat " "	:1"	:Forest litter	: 25 25 15 : 65:	30 hrs.:Ants
4	:6/21:" " "	:4900:	S	: " " " "	:1 $\frac{1}{2}$ "	: " "	: 5 45 10 : 60:	3 days: "
5	:6/21:" " "	:4910:	S	: " " " "	:3 $\frac{1}{2}$ "	:Forest litter, plants:	10 50 10 : 70:	3 days: "
6	:6/21:" " "	:4925:	S	: " " " "	:1 $\frac{1}{2}$ "	: " "	: 20 150 25 : 195:	12 $\frac{1}{2}$ hrs.: "
7	:6/23:" " "	:5350:	E	:Steep slope	:5"	: " " grass	: 25 25 5 : 55:	6 $\frac{1}{2}$ hrs.: "
8	:6/23:" " "	:5355:	E	: " "	:2"	:Grass and plants	: 25 25 5 : 55:	6 days: "
9	:6/23:" " "	:5360:	E	: " "	:3"	:Forest litter, plants:	25 25 5 : 55:	6 " : "
10	:6/23:" " "	:5365:	E	: " "	:1 $\frac{1}{2}$ "	: " " "	: 25 25 5 : 55:	6 " : "
11	:6/23:" " "	:5380:	E	: " "	:4"	: " " "	: 25 25 5 : 55:	6 " : "
12	:6/23:" " "	:5400:	open:	Top of wooded ridge:	:2 $\frac{1}{2}$ "	: " "	: 25 25 5 : 55:	6 " : "
13	:6/23:" " "	:5400:	"	: " " " "	:3 $\frac{1}{2}$ "	: " " "	: 25 25 5 : 55:	7 $\frac{1}{2}$ hrs.: "
14	:6/23:" " "	:5400:	"	: " " " "	:2"	: " " "	: 25 25 5 : 55:	6 days: "
15	:6/23:" " "	:5375:	W	:Steep slope	:5"	: " " "	: 25 25 5 : 55:	6 " : "
16	:6/23:" " "	:5375:	W	: " "	:2"	: " " "	: 25 25 5 : 55:	7 " : "
17	:6/23:" " "	:5365:	W	: " "	:2"	: " " "	: 25 25 5 : 55:	6 " : "
18	:6/23:" " "	:5360:	W	: " "	:1 $\frac{1}{2}$ "	: " " "	: 25 25 5 : 55:	6 " : "
19	:6/25:" " "	:5350:	W	: " "	:2"	: " " "	: 50 50 5 : 105:	4 " : "
20	:6/25:10"	:5400:	open:	Top of wooded ridge:	:2"	: " " "	: 500 500 : 1000:	6 " : "
21	:6/25:1 "	:5345:	W	:Steep slope	:3"	: " " "	: 50 50 : 100:	4 " : "
22	:6/26:" " "	:5340:	W	: " "	:1 $\frac{1}{2}$ "	: " " "	: 50 50 : 100:	2 " : "
23	:6/26:" " "	:5335:	W	: " "	:1"	: " " "	: 50 50 : 100:	3 " : "
24	:6/26:" " "	:5325:	W	: " "	:1 $\frac{1}{2}$ "	: " " "	: 50 50 : 100:	3 " : "
25	:6/27:" " "	:5320:	W	: " "	:2"	: " " "	: 50 50 : 100:	2 " : "
26	:6/27:" " "	:5300:	NW	: " "	:3 $\frac{1}{2}$ "	:Grass and plants	: 50 50 : 100:	4 " : "
27	:6/27:" " "	:5300:	S	: " "	:3"	:Forest litter, plants:	50 50 : 100:	2 " : "
28	:7/2 : " " "	:5200:	N	: " "	:5 $\frac{1}{2}$ "	:Moss and plants	: 25 70 5 : 100:	14 " :Ants, Centipedes
29	:7/2 : " " "	:5250:	N	: " "	:8 $\frac{1}{2}$ "	: " " "	: 25 70 5 : 100:	14 " :Centipedes
30	:7/2 : " " "	:5250:	N	: " "	:8 $\frac{1}{2}$ "	: " " "	: 25 70 5 : 100:	14 " : "
31	:7/2 : " " "	:5225:	N	: " "	:6"	: " " "	: 25 70 5 : 100:	14 " : "
32	:7/2 : " " "	:5300:	N	: " "	:3 $\frac{1}{2}$ "	:Forest litter, plants:	50 100 15 : 165:	4 " :Ants
33	:8/11:" " "	:5020:	N	: " "	:8 $\frac{1}{2}$ "	:Moss and plants	: 25 25 : 50:	14 " :Centipedes
34	:8/11:" " "	:5000:	N	: " "	:8 $\frac{1}{2}$ "	: " " "	: 25 25 : 50:	14 " : "

The plots as shown in Table IV were placed so as to represent the various types of ground cover and duff found on the area. All exposures as well as altitudes ranging from 4900 to 5400 were represented. Twenty-five of the plots were placed on steep slopes, five on level ground at the lower elevation, and four on the crest of a wooded ridge at 5400 elevation. An aneroid pocket barometer was used for determining the elevations. One of the plots covered ten square feet of ground surface. Two plots on a north facing slope were covered with wire screen cones one foot in diameter, and the remaining 28 were one foot square in size. It was found that the small plots were of a convenient size for close observations of ant activities. Dendroctonus monticolae larvae, pupae, and callow adults were taken from infested trees and immediately dropped on the plots. The large plot and a few of the small ones were covered with small strips of lodgepole pine bark. The average number of progeny of the mountain pine beetle used on the small plots was 81; on the large plot, 1000.

RESULTS OF OBSERVATIONS

Plot number one, Table IV, was kept under constant observation until all the exposed Dendroctonus monticolae brood, 95 in number, had been removed by ants. This was accomplished in $6\frac{1}{2}$ hours time. Twenty-five of the exposed brood consisted of callow adults, which required much more time for the ants to move than the larvae or pupae. The reason for this is explained under ant activities. Plots numbering 7 to 18 inclusive each contained 55 progeny of Dendroctonus monticolae, and were kept under close observation for eight hours, at which time 581 of the total 660 individuals or 88 per cent had been removed by various species of ants. Of the 12 plots, 7 to 18, two were entirely stripped during the eight-hour period of observation, and all but one larva was removed from each of four others.

Plots number 16 and 17 of this group were covered with considerable vegetation and only half of the progeny was removed by ants during the eight hours under observation. The plot containing 1000 exposed progeny was quickly located by ants. An examination made 24 hours after placing showed that 962 of the progeny had been removed. Ten larvae remained apparently undiscovered, however, for five days. The duration of the ~~test~~ shown in Table IV is from the time the progeny of the mountain pine beetle were exposed until the final examination was made, which consisted in removing all the duff from the surface of the plot and making a careful search in the removed duff and upper layer of mineral soil for any brood. The greatest ant activity was observed on plots with shallow duff on the south and east exposures in places having the largest amount of unobstructed sunlight.

Eight plots including the two that were inclosed by wire screen cones, were placed on a steep north slope. Seven of these plots were in duff consisting of deep moss, matted with lodgepole pine needles. This duff ranged from $5\frac{1}{2}$ to $8\frac{1}{2}$ inches in depth to the mineral soil. On this type of ground cover ants were almost entirely absent. In order to make the final observations at the end of 12 to 14 days, the duff had to be taken from the plot and broken up in small pieces for examination. No progeny of the mountain pine beetle exposed on the plots was found at the expiration of 14 days. Small centipedes seemed to be fairly well distributed in this moss type of duff. They were usually found near the surface of the soil. The duff in one of the two caged plots contained 31 centipedes and 16 were collected from the other. A number of these centipedes were confined in a cage along with progeny of the mountain pine beetle and kept under observation. It was found that the exposed brood was readily accepted by the centipedes as food.

Part II. WHITE PINE AREA, COEUR D'ALENE NATIONAL FOREST, IDAHO

The survival experiment as outlined under Scope, Part II, was conducted in a white pine stand on the Coeur d'Alene National Forest in conjunction with a mountain pine beetle project in which the peeling method was used. This project was begun early in May and finished during the latter part of June, 1929. Fourteen plots were used for observing the mortality of the exposed progeny of the mountain pine beetle. These were supplemented by observations at many groups of peeled logs.

TABLE V
Tabulated description of eight survival plots
with exposed brood of Dendroctonus monticolae under observation in 1929

Plot symbol:	Date established:	Location of plots	Size of plot:	Exposure:	Elevation:	Depth of duff:	Ground cover:
					Feet		
A	May 22	By peeled log near creek	1'x16'	W	3100	1 1/2"	Small plants
B	May 23	By peeled log on steep slope	1'x16'	E	3200	1 1/2"	Brush
C	May 27	By peeled log on steep slope	1'x16'	E	3200	1 1/2"	Brush
E	June 1	By peeled log near creek	1'x16'	E	3150	1 1/2"	Brush
J	June 14	By peeled log on high ridge	1'x16'	W	4100	1"	Small plants
K	June 14	By peeled log on high ridge	1'x32'	W	4100	1 1/2"	Small plants
M	June 22	Under peeled log in ravine	1'x32'	S	3150	1"	Brush
H	June 22	Under peeled log on steep slope	1'x32'	S	3150	1"	Brush

TABLE VI
The number of mountain pine beetle progeny used on eight plots and duration of plots and predatory agents responsible for destruction of larvae and pupae

Plot symbol:	Estimated No. of mountain pine beetle released	No. of mountain pine beetle brood added	Duration of plot	Predatory agents responsible for destruction of mountain pine beetle broods
A	4000	1200	6 days	Small mammals
B	2400	1000	7 "	Ants and small mammals
C	2000	300	5 "	" " " "
E	4800	500	3 "	Small mammals
J	3040	-	8 "	Small mammals
K	9600	500	12 "	" "
M	9000	-	10 "	Ants and small mammals
H	6200	-	12 "	Small mammals

The eight plots as shown in Tables V and VI were placed in various situations during an interval of a month (May 22 to June 22) and at elevations ranging from 3100 to 4100 feet, and including all but the north exposure. The approximate number of the brood of D. monticolae released on the plots varied from 2,000 to 9,600, the average being 5,130. Prior to May 31, the released broods consisted entirely of larvae. After the first of June pupae began to appear and by June 22 they comprised approximately 75 per cent of the exposed brood. Additional mountain pine beetle progeny were placed on five of the plots both to increase the number present to test out the ability of the predatory agents, and to give a definite number to keep under daily observation. The duration of the plots varied from three to twelve days, with an average of 7.7 days. Trapping for small mammals was conducted on these plots and the results are given in Table XI. Lasius niger var. americanus, a small soil inhabiting variety of ant, was observed on three of the plots. They were not seen carrying any of the D. monticolae larvae or pupae away from the location, but instead they placed the brood in a pile on the soil under the pieces of bark on the plots. In their efforts to move the larvae or the pupae they apparently punctured the skin with their sharp mandibles as all the brood placed in piles by the ants appeared to be dead. When the small mammals would appear on the plots where the ants had been working, the entire pile of the mountain pine beetle larvae or pupae would disappear and the ants would no longer be seen where their food supply had been. In addition to these eight marked plots similar observations were made throughout the area where control operations were conducted to check up on the effectiveness of ants and small rodents in the disposal of the brood. In no instance were D. monticolae larvae, pupae, or callow adults found under the removed bark strips or in the duff after a period of twelve days from the time of treating.

The six plots shown in Tables VII and VIII contained a number of sub-plots which were established over a space of 19 days at distances varying from one foot to 150 yards from the peeled white pine logs, and at elevations varying from 2900 to 4100 feet.

TABLE VII
Tabulated description of six survival plots containing sub-plots with brood of Dendroctonus monticolae under observation in 1929

Plot:	No. of:	Date :	: Sub-plots:	Size of:	:	:	:	:	:
sym-:	sub-:	estab-:	: covered :	plot :	: Expo-:	Ele- :	: Depth of:	:	:
bol :	plots:	lished:	Location of plots	: with bark:	area :	: sure :	vation:	duff :	Ground cover
D :	5 :	5/27 :	150 yds. from treated logs:	all	:1'x8'	: W :	3250 :	1 1/2"	: Brush
F :	20 :	6/5 :	At group of treated logs :	"	:1'x16'	: W :	3100 :	1 1/2"	: Small plants
G :	20 :	6/8 :	By peeled white pine logs :	"	:1'x16'	: E :	3150 :	1 1/2"	: Brush
N :	20 :	6/13 :	" " " " " :	"	:1'x16'	: W :	3200 :	1"	: Small plants
I :	20 :	6/13 :	20 ft. from treated logs :	Two	:1'x16'	: W :	3200 :	1"	: " "
L :	20 :	6/14 :	50 " " " " :	None	:2'x20'	: S :	4100 :	1 1/2"	: Brush

TABLE VIII
Number of mountain pine beetle brood used on six plots containing sub-plots, the duration of plots, and the predatory agents responsible for destruction of larvae and pupae in 1929

Plot:	No. of:	No. of m.p.b.:	: Disposal of mountain pine	: Predatory agents responsible
sym-:	sub-:	: brood on sub-:	: beetle broods and total	: for destruction of mountain
bol :	plots :	plots :	: on plot : duration of plots	: pine beetle broods (1).
D :	5 :	100 :	500 : 100% in 8 days :	Small shrew
F :	20 :	10 :	200 : 98% in 9 days: " " 11 " :	Small rodents
G :	20 :	10 :	200 : 99% " 6 " : " " 8 " :	Small shrew
N :	20 :	10 :	200 : " " " " : " " 9 " :	Small rodents
I :	20 :	10 :	200 : 96% " " " : " " 8 " :	" "
L :	20 :	10 :	200 : 98% " 9 " : " " 12 " :	Centipedes and shrews

(1) See animal activities.

The plots near the treated logs were placed where the released mountain pine beetle broods had been removed by predatory agents some time previously. The object of this was to find out, if possible, whether small rodents are attracted in search of food to logs lying on the ground, how long and thoroughly they will search for food in the same area, and also whether pieces of bark lying on the ground would act as an added attraction. Three of the plots were placed near treated logs and three some distance away, one being 20 feet, one 50 feet, and one 150 yards from the nearest peeled logs. The sub-plots near logs were covered with pieces of bark that had been removed from the treated logs. On Plot I only two of the sub-plots were covered with bark, and on Plot L no bark was used. In placing Plots I and L a small portion of the duff was carefully pushed to one side, the brood of D. monticolae placed on the soil, and the duff replaced to show as little disturbance as possible.

The average duration of the plots beside treated logs was 8.3 days, of those farther off, 10.3 days.

In locating white pine trees attacked by the mountain pine beetle on the Steamboat Creek Drainage it was found that 33 per cent of the infestation on four sections was situated on steep slopes. After peeling the upper portion of the logs from many of these trees, and in attempting to turn them over to treat the under side, the logs would slide down the steep slope and the peeling would be completed some distance from where the tree was felled. Three of the plots, D, I, and L were used to supplement the observations made on this phase of the peeling method.

Part II. WHITE PINE AREA, CLEARWATER NATIONAL FOREST, IDAHO

The survival experiments in the white pine stands on this area were carried on in conjunction with a mountain pine beetle control project in which the peeling method was used. The experiments consisted mainly in

observing the mortality of the exposed progeny of Dendroctonus monticolae at groups of treated trees, and in ascertaining the kinds and relative abundance of ants and small rodents inhabiting the control area. Observations on the disposal of the exposed progeny were confined to the duff and bark strips under and near freshly peeled infested logs at five different groups varying in number from 2 to 40 treated trees. The distribution of ants was secured from observations and collections in the control area. The kinds and abundance of small rodents were determined by trapping.

The control work was started on May 2, 1930 and finished during the latter part of the month, and during this time 577 infested white pines were felled and peeled. Five days after the control operations started, the observations on the mortality of the exposed progeny were begun. The snow had recently disappeared from the area and the ground was cold and wet. No evidence of ants or rodent activity in the vicinity of the peeled logs was seen at this time, though great numbers of larvae of the mountain pine beetle were visible on the bark strips peeled from the logs and in the duff. By May 9, the weather began to turn warm and the effect of the sunshine on the duff was easily noticeable. Three days later, small ants, Lasius niger var. americanus were beginning to leave their underground nests. They were particularly common in the thick duff at the base of standing trees. By May 14, the ants were found in great numbers crawling about in the duff and over the bark strips around the peeled logs throughout the control area, while evidence of small rodents was also noted at this time around the peeled logs. Very few of the exposed larvae remained by this date. The final examinations of the duff around the treated logs was made on May 15 and 16. Ants were found in increasing numbers, and a diligent search in the duff revealed only an occasional larva which probably escaped the predators, by being covered with several thick pieces of bark. The kinds and abundance of the small rodents found on the area are given under the heading on small mammals.

Part II. WHITE PINE AREA, KANIKSU NATIONAL FOREST, WASHINGTON

Four survival plots were established on this area, two on June 10, and two on the following day. The site selected for the experiment was on a large heavily timbered flat bordering on Sullivan Creek. A number of white pines attacked and killed by the mountain pine beetle were felled on this flat during October, 1929. These felled trees furnished the progeny of *Dendroctonus manticolae* and the setting for the study.

TABLE IX

Tabulated description of four survival plots containing sub-plots with brood
of D. monticolae under observation in 1930

Plot	No. of	estab-	Sub-plot	Size of	Depth of				
sym-	sub-	lished	covered	plot	Expo-	Ele-	pine-		
bol	plots:	1930	with bark:	Location of plots	area	sure:	vation:	needles	Ground cover
				:30 yds. from infested trees:					:Dense shade,
A	10	6/10	8	: on large flat	:2' x 20'	:open	: 2620	: 1½"	:no vegetation
				:On large flat among four					:Dense shade,
B	10	6/10	2	: windfalls	:5' x 8'	: "	: "	: 1½"	:no vegetation
				:On large flat near and					:Dense shade,
C	6	6/11	5	: under windfalls	:5' x 6'	: "	: "	: 2"	:no vegetation
				:On large flat under in-					:Reproduction
D	5	6/11	5	: fested white pine log	:1' x 16'	: "	: 2600	: 1½"	:and small plants

TABLE X

Number of mountain pine beetle progeny used on four plots containing sub-plots,
the duration of sub-plots, and the predatory agents responsible for the destruction of the exposed
progeny in 1930

Plot.No.of:No. of m.p.b.:		:Disposal of mountain pine		:Predatory agents considered responsible	
sym-:sub-:	brood on	:Total No.:	beetle broods and total	: for destruction of the mountain	
bol :	plots:sub-plots	:on plot	:duration of plots	: pine beetle broods	
:	:	:	:	:	
A :	10 : 100 larvae	: 1000	:94% in 8 days:	100% in 27 days:	ants (<u>Lasius niger</u> var. <u>americanus</u>)Centipedes.
:	:100 lar.on 6	: 800	:92% " 4 "	:100% " 12 "	: " " " " " (Centipedes,
B :	10 : 50 lar.on 4	:	:	:	woodmouse)
:	: 50 M. A.	: 300	:91% " 5 "	:100% " 8 "	:Callow adults by ants. Mature adults
:	:110 callow	:	:78% " 5 "	:100% " 31 "	: not known if destroyed or migrated
C :	6 :190 mature	:	:	:	: (ants on plots)
:	:100 mature	:	:	:	:Swarms of ants (<u>L. niger</u> var. <u>americanus</u>)
D :	5 : adults	: 500	:92% " 3 "	:100% " 26 "	: on plot during life of plot

The four main plots shown in Tables IX and X were divided into sub-plots, two main plots having ten each, one having five and the remaining one, six. A total of 2600 mountain pine beetle progeny were used, including 800 adults, 110 of which were callow. The sub-plots on Plots A and B were formed by carefully moving a small portion of the duff, dropping the D. monticolae larvae on the soil and replacing the duff to show as little disturbance as possible. This type of plot was used to determine how thoroughly ants and small mammals search the duff in quest of food. Snap traps without bait were set under the bark on three of the sub-plots of Plot A, and one of the sub-plots of Plot B. Twenty-four hours after placing the plots, ants (lasius niger var. americanus) were found working on 16 of them, the remaining four apparently escaped notice. Ninety-four per cent of the 1000 mountain pine beetle larvae on Plot A was taken by the ants in eight and 92 per cent of the 800 larvae from Plot B in four days. Nineteen additional days elapsed before the final disappearance of the remaining six per cent of the brood on Plot A. This was the longest period of time required for the disposal of larvae from any of the plots during the entire survival study. Plots C and D contained only adults of the mountain pine beetle. Included in the 500 adults used on Plot C were 110 which were callow. All but one of the six sub-plots on this plot were covered with bark strips. The uncovered one which contained adults was the first to be entirely depleted. An examination made 48 hours after placing disclosed only two adults; these disappeared the following day. Centipedes were seen on this sub-plot but no ants were observed. This was the only one of the eleven sub-plots containing adults on which ants were not found. It is possible that the lack of the bark strips over the duff caused the adults to

stray away from the sub-plot if they were not taken by predators. The bark strips may have acted as an attractive feature in inducing ants to enter the other sub-plots. At the end of four days, 48 of the adults on Plot C were found in short tunnels in the bark strips, and two mature adults and 23 callow ones were found in the duff. Of the 23 callow adults, 12 had been placed in a pile by Lasius niger var. americanus and fragments of several others were lying near by. At the end of 8 days these were all missing and all but the 48 adults that had tunneled in the bark strips. These remained in the bark until some time between July 9 and 12, or practically one month after being exposed on the plot. On Plot D 100 apparently mature adults were placed on each of the five sub-plots and the duff covered with bark strips. This plot was established under a felled infested white pine resting on windfalls. An examination made the day following the placing showed that all the sub-plots were swarming with Lasius niger var. americanus and that only 82 of the 500 adults could be accounted for. Fragments of adults could be seen on one of the sub-plots. At the end of seven days number of adults remaining had dwindled to 48. These all disappeared from the bark strips by July 7, or 26 days after placing. The ants were still on the sub-plots at the final examination on July 7.

PREDATORS DESTROYING THE EXPOSED PROGENY OF THE MOUNTAIN PINE BEETLE

On the Bitterroot area ants and centipedes were found to be the only known factors in the destruction of the exposed progeny. The ants working on the south, east and west exposures, and the centipedes on the north. No trapping experiments were conducted on this area.

In the white pine stands a variety of fauna was found to exist, which appeared to be governed to a certain extent by the kinds and the situation of the ground cover and the amount of sunshine present during the spring months.

The survival experiments conducted on the Coeur d'Alene, Clearwater, and Kaniksu National Forests in Idaho and Washington, showed that both ants and small rodents were very beneficial.

ANTS INHABITING THE AREAS

Species inclosed in parentheses were found to be beneficial and are listed in the order of their importance.

BITTERROOT NATIONAL FOREST, MONTANA

(Formica rufa aggerans Wheeler)

(Formica fusca var. subaenescens Emery)

(Formica fusca var.)

(Leptothorax sp.)

(Tapinoma sessili Say.)

Lasius niger var. americanus Emery

Camponotus herculeanus var. whymperi Forel.

Myrmica mutica Emery

COEUR D'ALENE NATIONAL FOREST, IDAHO

(Lasius niger var. americanus Emery)

Camponotus herculeanus var. whymperi Forel.

Formica fusca var. neorufibarbis Emery

CLEARWATER NATIONAL FOREST, IDAHO

(Lasius niger var. americanus Emery)

Formica fusca var. gelida Wheeler

Formica rufa var.

KANIKSU NATIONAL FOREST, WASHINGTON

(Lasius niger var. americanus Emery)

Formica fusca var.

Formica dakotensis var. montigena Wheeler?

Tapinoma sessile Say.

Myrmica brevinoides var.

ANT ACTIVITIES

Formica rufa aggerans Wheeler:

This was the most common and aggressive ant found on the Bitterroot area, particularly at the lower elevations. It constructs large nest mounds of fallen pine needles, small twigs, and bark flakes from lodgepole pine. These mounds were fairly common on the large wooded flats along the East Fork of the Bitterroot River.

The progeny of Dendroctonus monticolae exposed on survival plots on these flats were soon located by these ants and rapidly removed to their nests. The workers collected from the survival plots varied from 4 to 5 mm. in length. They were unable to carry their prey in their jaws, and had to drag them over the duff, often requiring considerable time to cover a few yards distance. Callow adults offered the greatest resistance to being moved. They would persistently cling to needles or twigs, or any object coming in contact with their tarsal hooks. Often several ants would struggle with an adult until they would succeed in turning it on its side or back, then an individual ant would seize it by an antenna or leg and drag it over the duff, though the journey was often interrupted by the beetle catching hold of some object. On the plots where these ants were found removing the brood, they appeared to leave a trail scent or to have some other means of following a very exact course in entering and leaving the plot. One particular plot (No. 1), Table IV, which was under constant observation for 6½ hours, fully 95% of the ants entered and returned over

a strip of ground less than 3 inches wide.

Formica fusca var. subaenescens Emery:

This species ranked second in importance in destroying exposed progeny of D. monticolae on the survival plots on the Bitterroot area. The workers collected from the plots varied from 3 to 6 mm. in length. The larger ants were able to carry their prey in their jaws and move rapidly over the duff.

It builds large gravel mounds and is abundant both on the flats and on the higher ridges in the lodgepole pine area.

Formica fusca var.:

Another variety of Formica fusca was found working on the plots, particularly those on the ridges. They were capable of carrying the progeny of D. monticolae in their jaws and helped dispose of a large per cent of the exposed broods.

Leptothorax sp.:

A small soil inhabiting species that was fairly common on the Bitterroot area. The workers collected from the plots varied from 3 to 4 mm. in length. They were unable to carry the exposed brood. They moved in and out on the plot within a well defined area.

Tapinoma sessile Say:

This soil inhabiting species was the smallest ant found working on the plots on the Bitterroot area. Specimens collected from the plots averaged 2 mm. in length. As soon as they located the exposed brood, large numbers of them would congregate on the plot. They would gather the larvae or pupae of the mountain pine beetle together in a pile formed on the mineral soil under the duff. It appeared that in

their efforts to move the brood, they would pierce the cuticle and the body juices would either be consumed by the ants or lost in moving, as only the flattened skins were found collected in a pile. This species was also found on the Kaniksu National Forest in the vicinity of the survival experiment, but none were collected from the plots.

Lasius niger var. americanus Emery:

This soil inhabiting species averaging 3 mm. in length was found on the survival plots on all four of the areas. On the Bitterroot, a few of these ants would appear on the plots, and examine the exposed brood, but none were observed attempting to move any of them away. On the Coeur d'Alene Forest they gathered in large numbers on the plots, particularly those covered with bark strips. They would assemble the larvae and pupae in a pile on the mineral soil under the layer of duff. Not being able to carry their prey, they dragged the brood down through the duff. This species was very abundant on the Clearwater National Forest, and were found in large numbers working on the exposed broods around the peeled logs. On the Kaniksu National Forest this species was also abundant, and was found working on all the plots, destroying the exposed adults as well as the larvae and pupae.

The other species of ants appearing on the list were collected on the areas where the survival experiments were conducted, but none were found working on the plots.

CENTIPEDES

Centipedes were collected from the duff on the plots on the Bitterroot, Coeur d'Alene, and Kaniksu National Forests. They were found to be more numerous on the Bitterroot area, and there, were

accredited with the destruction of the exposed progeny of the mountain pine beetle. On all the other areas, ants were associated with the centipedes, consequently no conclusions could be formed as to their beneficial value.

GROUND BEETLES

Ground beetles belonging to the family Carabidae were found occasionally on the plots and under pieces of bark peeled from infested logs on the control areas. As these beetles are generally nocturnal in habits no evidence of their feeding on the progeny in the duff was secured, but it is quite probable that they assisted in destroying the exposed broods.

RODENTS

The abundance and kinds of small rodents on three of the areas was determined by trapping methods. A few of the rodents were taken in live traps, the balance in snap traps. A tabulated description of the areas, location of traps, and catch is given in Tables XI and XII.

TABLE XI
ABUNDANCE OF SMALL RODENTS
ON THREE OF THE SURVIVAL AREAS, AS DETERMINED BY TRAPPING

Area	Timber type	Location of traps	No. of traps	Number of single trap nights	Number of rodents caught
Bitterroot N. F.		No trapping in this area			
Coeur d'Alene N. F.	White pine	On survival plots	21	121	21
1929		Near " "	6	54	0
		At treated trees	17	32	4
Clearwater N. F.	White pine	Acre plot	40	240	13
1930	" "	Ridge plot	20	80	7
	" "	Trail plot	60	180	9
	" "	Logged area	10	60	10
Kaniksu N. F.	White pine	Near plots	10	90	3
1930		On plots	5	60	1
Total				917	68

TABLE XII
LIST OF SPECIES OF RODENTS SHOWN IN RELATION
TO THEIR ABUNDANCE, AS DETERMINED BY TRAPPING

Area	White-footed mouse	Shrew <u>S. c.</u>	Shrew <u>S. o.</u>	Vole <u>M. m.</u>	Vole <u>C. g.</u>	Chipmunk	Rocky mt. jumping mouse
	<u>P. m.</u>	<u>cinereus</u>	<u>obscurus</u>	<u>mordax</u>	<u>saturatus</u>	<u>E. r.</u>	<u>simulans</u>
Bitterroot							
Coeur d'Alene N. F.	12	3		4		2	4
Clearwater N. F.	5	19			9	6	
Kaniksu N. F.	2		1			1	
Total	19	22	1	4	9	9	4

SMALL RODENTS TRAPPED ON THE
AREAS AND LISTED IN ORDER OF THEIR IMPORTANCE

Coeur d'Alene National Forest (northern Idaho):

White-footed mouse (Peromyscus maniculatus artemisia (Rhoads))

Vole (Microtus mordax mordax (Merriam))

Shrew (Sorex cinereus cinereus Kerr.)

Chipmunk (Eutamias ruficaudus simulans Howell)

Rocky mountain jumping mouse (Zapus princeps princeps Allen)

Clearwater National Forest (west central Idaho):

Shrew (Sorex cinereus cinereus Kerr.)

Vole (Clithronomys gapperi saturatus Rhoads)

White-footed mouse (Peromyscus maniculatus artemisia (Rhoads))

Chipmunk (Eutamias ruficaudus simulans Howell)

Kaniksu National Forest (northeastern Washington):

White-footed mouse (Peromyscus maniculatus artemisia (Rhoads))

Chipmunk (Eutamias ruficaudus simulans Howell)

Shrew (Sorex obscurus obscurus Merriam)

A comparison of the various kinds of small mammals secured by trapping on the three areas shows a close similarity in both genera and species. The abundance of the species, however, varied considerably with the different areas. In the white pine stands on the Coeur d'Alene National Forest, the white-footed mouse was very common, ranking first in numbers and importance. On the Kaniksu National Forest this species, while given first place on the list, it was not considered abundant. This species was found to be third in importance on the Clearwater National Forest.

The red-backed mice or voles were abundant on the Coeur d'Alene National Forest, common on the Clearwater National Forest, and scarce

on the Kaniksu National Forest in the areas where the experiments were conducted. The same species of small shrew was found on two of the forests and represented by a species similar in size and habits on the third. The same species of chipmunk was found on all three of the areas, but most abundant on the Coeur d'Alene National Forest. The rocky mountain jumping mouse was taken only on the Coeur d'Alene area.

A few of the rodents were trapped alive on the plots on the Coeur d'Alene area and confined in cages for observing their method of searching the duff for food and also the amount consumed daily. The floor of the cages was covered with a layer of duff similar to that found around the peeled logs, and a known number of mountain pine beetle progeny were placed under pieces of bark in the cages. The white-footed mice and chipmunks would scratch out enough pine needles to permit easy access to the brood under the bark. The mice would scratch thoroughly through the duff securing all of the brood, but the chipmunks would often leave or overlook a few of the larvae or pupae.

Only one shrew (Sorex cinereus cinereus Kerr.) was captured alive and observed in confinement. This shrew was able to travel quite freely through the duff of pine needles on the bottom of the cage and under pieces of bark, leaving small holes in the duff where it would pass in and out. The voles would also search the duff very thoroughly for the exposed progeny. The rocky mountain jumping mouse was able to travel quite rapidly through the loosened duff in the cage, but it only lived a short time and no observations as to its methods of feeding on the Dendroctonus monticolae larvae or pupae were secured.

On the Coeur d'Alene and Kaniksu areas trapping for the small rodent was conducted by or in the immediate vicinity of peeled logs, or survival plots. On the Clearwater area the trapping was carried on at a distance

of a mile from the treated groups. It was believed that this method would give a better idea of the general abundance over the area as there would be no added attraction in the way of freshly felled trees and the large supply of food supplied by the exposed progeny of the mountain pine beetle. Of the 65 rodents trapped on the three areas as shown in Table XII, the shrews represented 34% of the catch, the white-footed mice, 28%; and the remaining 38% was divided among the four other species.

TABLE XIII
TABLE SHOWING FEEDING ACTIVITIES OF SMALL RODENTS
CAPTURED ALIVE ON SURVIVAL PLOTS ON THE COEUR D'ALENT NATIONAL FOREST
AND CONFINED IN CAGES

Rodent	: :Period : of : captivity	:Daily :average of :D.m. progeny: :eaten.	: :Other :food :eaten	:Total :No.of :Dm pro- :geny eaten:	: : : :
Chipmunk #1	: 24 hrs.:	250	:None	: 250	:Liberated
Chipmunk #2	: 96 hrs.:	250	:Rolled oats	1000	: "
Shrew	: 25 1/2 hrs.:	550	:None	: 550	:Died in cage
White-footed mouse, male	: 168 hrs.:	559	:Rolled oats	3915	:Liberated
Vole	: 120 hrs.:	345	: " "	: 1725	: "
Rocky mt. jumping mouse	: 36 hrs.:	150	:None	: 150	:Died in cage
Female white-footed mouse and five young	: 22 days: :fed D.m.:	1277	:Rolled oats :Bread	2555	:Liberated
reared in captivity	: 48 hrs.:		:Crusts		

The chipmunk was the only rodent confined that failed to eat all the progeny of D. monticolae provided. Two hundred and fifty larvae or pupae seemed to be the daily limit, above that number and any damaged ones were discarded. As it was thought that a lack of exercise, due to confinement, might influence the amount of food consumed daily, a large wheel was added to the cage for chipmunk #2. This wheel was used fairly regularly particularly early in the mornings, but the added exercise failed to have any apparent influence on the amount of food consumed.

Only one shrew was captured alive on the plots, and it lived in captivity for only a trifle over a day. As it was extremely active, it may have worried itself to death.

Several of the voles were kept in captivity and they also consumed the larvae and pupae readily as food.

The male white-footed mouse listed in Table XIII was exceedingly fond of the progeny of D. monticolae seemingly preferring the larvae or pupae to any other kind of food. The maximum number devoured by this mouse for a period of eleven hours, was 728. The female white-footed mouse and young were kept in captivity for 22 days. The young mice were born shortly after the female parent was captured. No progeny of D. monticolae were fed to the young mice until they were 20 days old, at which time they were apparently half grown, and devoured the larvae, pupae, or new adults in preference to other food placed in the cage. The daily average consumed for the two days was 1277.

The one specimen of rocky mountain jumping mouse lived but a short time in captivity. It may have died from starvation as only a small number of D. monticolae progeny had been placed in the cage as food.

SUMMARY AND CONCLUSIONS

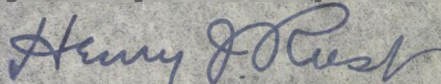
The peeling method of control was devised by the Forest Insect Division of the U. S. Bureau of Entomology to meet the demands of timber owners for protection against tree killing barkbeetles that develop between the bark and wood. The success of the method was based on the assumption that in removing the bark from infested trees during the feeding stage of the brood, and exposing them to the weather, death would soon result. The method had been in use for a number of years when it was discovered that the post-feeding stage of the mountain pine beetle could successfully mature in the duff. The final development of the exposed progeny, however, was dependent to some extent on the prevailing weather conditions, but most particularly on not being discovered by predators, such as ants, centipedes, and small rodents.

The experimental work described was divided into two parts; first, to ascertain the possibility of the exposed progeny surviving in the duff when protected from predators; and second, the chances of the exposed progeny maturing on the forest floor when unprotected. Caged experiments to protect the exposed brood were conducted in lodgepole pine stands in Montana, and in white pine stands in Idaho and Washington. The final results of the first part of the work showed that if thoroughly protected from predators, a large per cent of prepupal larvae, pupae, and callow adults could mature in the duff and successfully attack healthy standing trees. The second part of the experiment consisted of extensive observations both at established plots and in the duff by the peeled infested trees on the control areas. The results of this part of the study showed that a very few of the exposed progeny in the duff on either the plots or around freshly peeled infested trees, remained undiscovered by predators after a period of 14 days. The final results of the experiment demonstrated that on areas where ants, centipedes, and small rodents such as described in this paper are present, the peeling method of control can be conducted with good success during the larval and pupal stages of the mountain pine beetle.

ACKNOWLEDGMENT

The writer desires to express his appreciation and thanks to Mr. W. M. Mann for determining the ant species; Dr. H. E. Ewing, the centipedes; Mr. W. S. Fisher, the ground beetles; the U. S. Bureau of Biological Survey, the rodents; and to the Personnel of the Coeur d'Alene Field Station, U. S. Bureau of Entomology for valuable help and suggestions.

Respectfully submitted,



H. J. Rust, Senior Scientific Aid.